Vibrating Wire Strain Gauges

Introduction

Vibrating wire sensors are used in the mining, civil and hydrological engineering, and other geophysical disciplines.

There are two versions of the *DT80 Range* dataTaker data loggers with specialized hardware to support the vibrating wire strain gauges, these are the;

dataTaker DT80G GeoLogger
dataTaker DT85G GeoLogger

The *GeoLoggers* are functionally the same as the *dataTaker DT80* and *dataTaker DT85* data loggers, with the addition of an internal vibrating wire strain gauge support module and associated commands for reading vibrating wire sensors.

The *GeoLoggers* support all the signal types and functions available in the *dataTaker DT80* range data loggers.

Vibrating wire strain gauges (VWSG) are widely used for measuring strain in geotechnical applications. A gauge consists of a tensioned steel wire whose resonant frequency changes as deflections causes the wire's tension to change. In practice these elements are used in various sensors designed to measure soil pore pressure, strain in structure, rock stress, overburden pressure, etc. The *GeoLoggers* support vibrating wire strain gauges with resonance between the range of 500 Hz and 5 KHz.

Prerequisite

This worked example assumes basic knowledge of;
1. *dEX interface or DeTransfer*
2. *dataTaker* programming language. (When using DeTransfer)
3. Connecting and programming thermistors and temperature sensors.

Requirements

Hardware;
1. *DT80G* or *DT85G dataTaker* data logger. Version 8.06.0001 firmware or later.
2. VWSG based sensor.

Software;
1. *dEX* interface.

or
2. *DeTransfer*.

Manuals;
1. *DT80* User manual Version UM-0085-B1 or later
2. VWSG specification, User manual or installation guide.

Quick start

VWGS sensors will typically have either two wire or 4 wire configurations.
If the sensor has 4 wires then one pair of wires will be for the VWSG and the other will be for a thermistor temperature sensor. Please refer to the manufacturer's specifications or user manual for full wiring details of your specific sensor.

Sampling the VWSG

1. Connect the VWSG to the + and – terminals of a *dataTaker* analog channel.

Note: Cable shielding is to be connected to either the Digital Ground or the ground screw terminal.

2. When using *dEX* web based configuration interface

a. Open your web browser and enter the TCP/IP address of your *DT80* series Geologger.

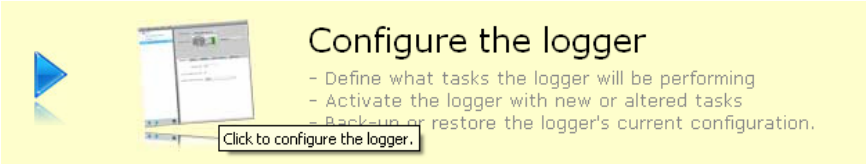
Configure the logger
- Define what tasks the logger will be performing
- Activate the logger with new or altered tasks
- Back-up or restore the logger's current configuration.
Click to configure the logger.

Figure 1 Accessing *dEX* configuration builder

b. In the Menu tree select Schedule_1 then click on "Add" in the menu bar

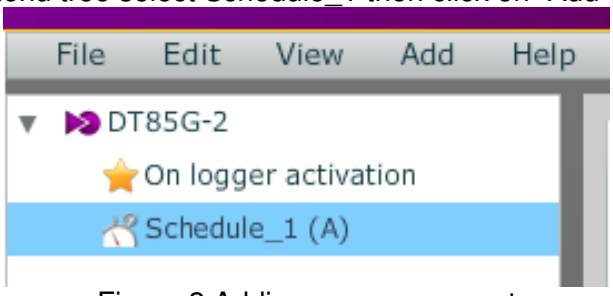

Figure 2 Adding a measurement

c. Expand out the add menu following the path Measurement -> Geotechnical -> Vibrating Wire and click on Vibrating wire menu option.

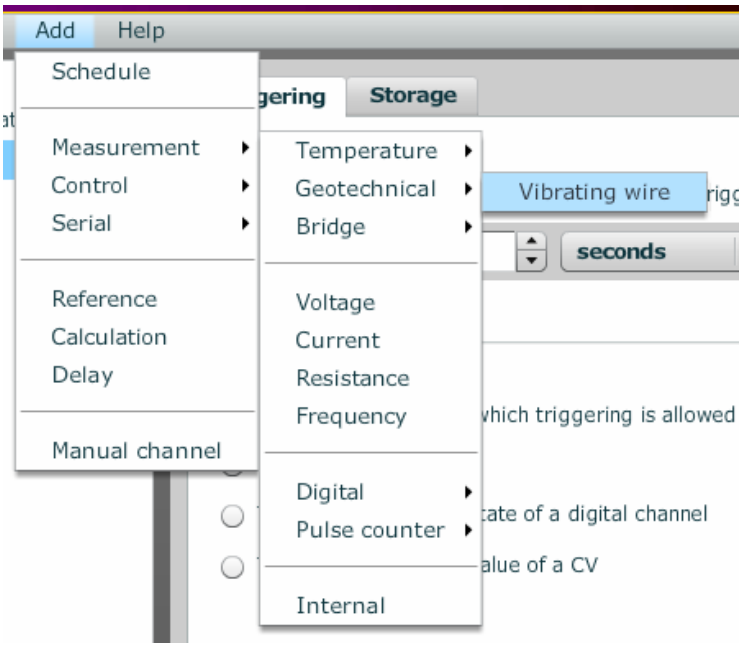

Figure 3 Adding a Vibrating Wire channel type

d. In the tree view give the channel a unique and meaningful name. To accept the name click on the tick. Note: This name will be referred to in later calculations.

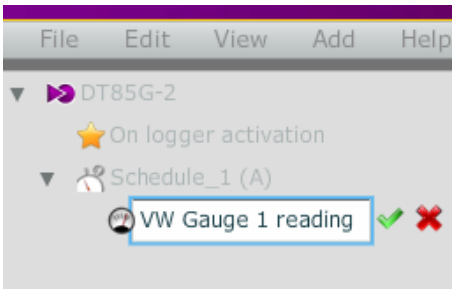

Figure 4 Naming the channel

e. In the view pane, click on “Select wiring” and select the first wiring option.

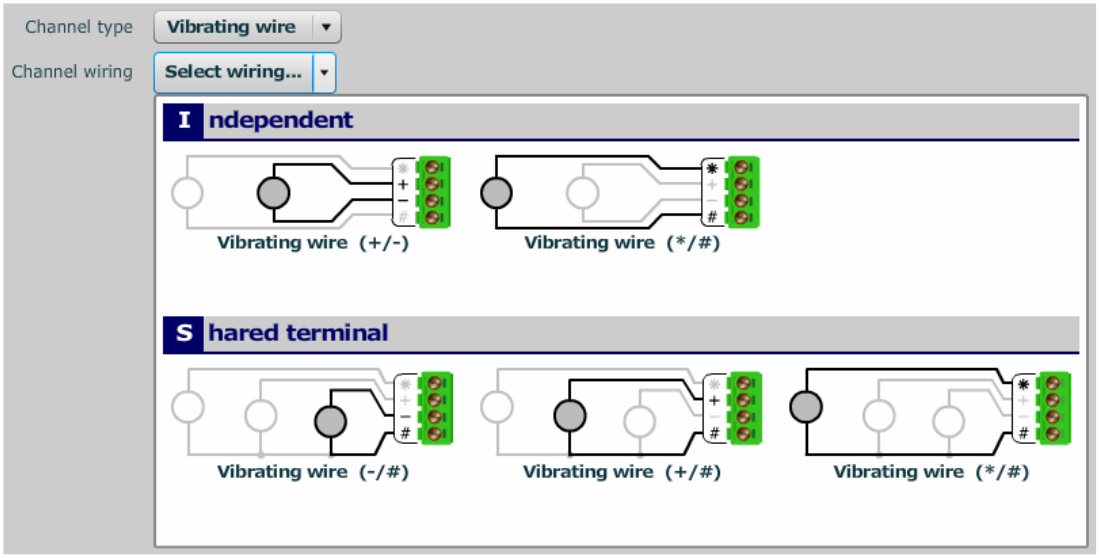

Figure 5 Selecting wiring type

f. In the view pane, click on the channel selector and select the analog channel number the vibrating wire sensor is physically connected to.

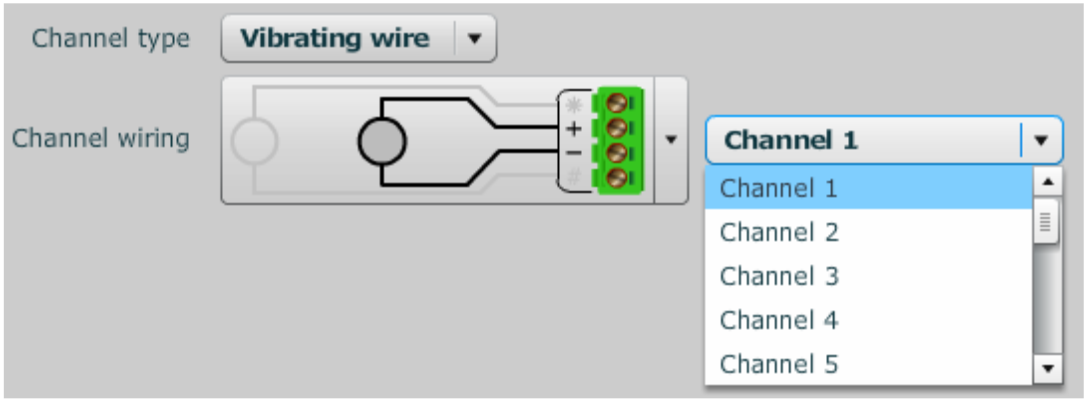

Figure 6 Selecting analog channel number

g. To send the configuration to the logger, on the menu bar, Click on “File” -> “Save to logger”

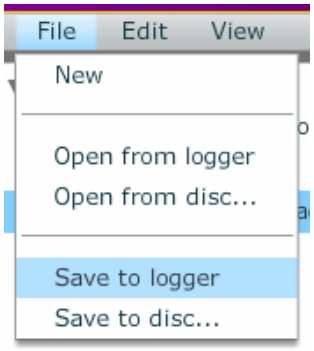

Figure 7 Sending configuration to logger

3. When using the *dEX* command window or *DeTransfer*.
a. Connect to the *GeoLogger.*
b. In the send window type the command nFW. Where n is the analog channel number the VWSG is connected to. This will cause the *GeoLogger* to take a single reading from the VWSG.
c. Sample result will be returned to the receive window.

Vibration Wire Support in detail

The *GeoLoggers* generate a 'current pulse' to excite or 'pluck' the wire in the vibrating wire gauge. Immediately following excitation, the resonant frequency of the vibrating wire is measured. The advantage of the plucking pulse method is that a fixed pulse is able to stimulate a wide range of gauges. This greatly simplifies channel programming for the user.

The balanced plucking pulse is approximately 200 µS long and up to 36 Volts in amplitude. The pulse has a current source characteristic that provides automatic cable length compensation.

The *GeoLogger* has a high gain low noise signal amplifier with transformer coupling on the input.

The amplified signal is filtered using band pass filters (500Hz to 5KHz) and a phase lock loop to reduce frequency noise before the frequency is measured by a precision frequency counter. Signals of the order of tens of microvolts can provide useful readings.

Transformer coupling ensures very high common mode rejection, a characteristic that is needed to reject 50/60 Hz mains noise and other interfering noise. A block diagram of the pulse pluck method is illustrated below (Fig. 8.)

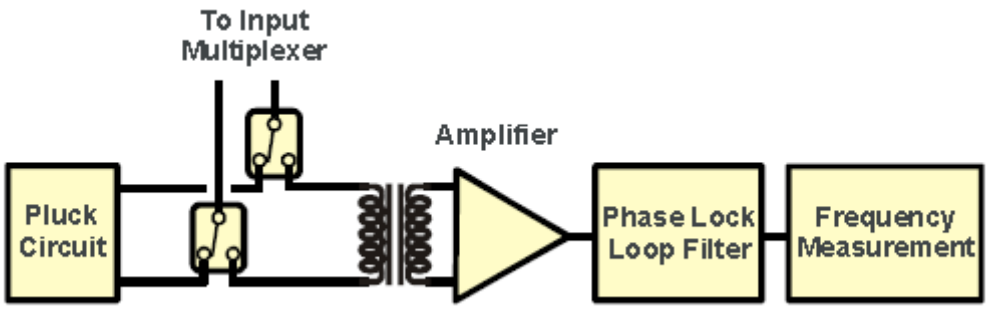

Figure 8 Block diagram of Vibrating Wire components

Connecting Vibrating wire strain gauges

Differential Inputs

The preferred method for connecting vibrating wire strain gauges to the *GeoLogger* is differential connection, where the sensor is connected between the + and – or the * and # terminals of the *GeoLogger* analog input channels.

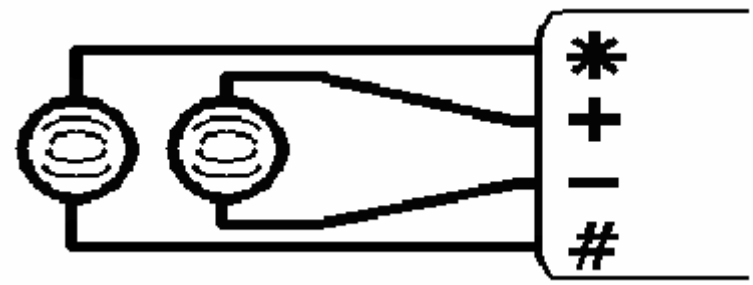

Figure 9 Wiring for independent differential inputs

Single ended inputs

Vibrating wire strain gauges can also be connected to the *GeoLogger* as single ended analog inputs. The signal from the sensor is connected between the +ve, –ve or ✳ terminal, and Analog Return terminal. Single ended connection for vibrating wire strain gauges is illustrated in Figure 10 below

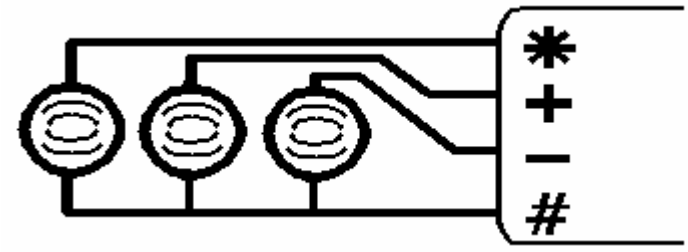

Figure 10 Wiring for single ended inputs

The connection of vibrating wire strain gauges as single ended inputs referenced to Analog Return is best used where

1. cable lengths are relatively short (< 100 meters)
2. vibrating wire strain gauges have good sensitivity

Because of the great range in vibrating wire strain gauge sensitivity, it is difficult to predict the operating limits. It is suggested that where cable lengths are in excess of 100 meters, a test be conducted with the gauges to be deployed. Single ended connection of vibrating wire strain gauges allows up to three sensors to be connected to each analog input channel, and up to 15 sensors to be connected to a *DT80G GeoLogger* or up to 48 sensors on the *DT85G GeoLogger*.

The number of sensors can be increased by using the CEM20 channel expansion module on Series 2 *DT80G* or *DT85G dataTaker* data loggers.

Measuring Gauge Temperature

Most vibrating wire strain gauges are sensitive to temperature fluctuations. Where a vibrating wire strain gauge temperature is likely to change significantly, the gauge temperature should be measured.

The vibrating wire strain gauge temperature can be measured using IC temperature sensors, RTDs or thermistors supported by the *GeoLogger.*

Depending on the internal wiring of the vibrating wire strain gauge, it is often possible to measure the vibrating wire frequency, and a resistive temperature sensor (thermistor), on a single analog input channel.

If the sensor is fitted with an internal 2 wire thermistor then the thermistor must be wired between the * and # terminals while the vibrating wire gauge can be connected as a differential input. (Fig. 11.)

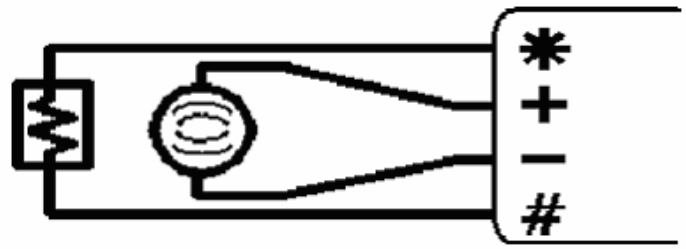

Figure 11 Wiring for thermistor and differential input

Grounding of cable shielding.

A shielded signal cable is recommended. Shielded wiring will reduce the potential risk of electrical noise. The preferred shield connection point is either one of the *GeLlogger* digital ground (D GND) terminals, a case ground terminal strip or the ground point on either end of the *DT80* range end plates (Refer Fig 12.)

Figure 12 *DT80 range dataTaker* showing grounding point (Silver screw)

Typical Calculations

The output from VWSG sensors and the FW channel type is in Hz and need to be converted into engineering units.

The examples provide are based on real sensors but the exact mathematics for converting frequency to engineering units will be defined by the manufacturer of the sensor. Please refer to the manufacturer's literature for how to convert the sensor output to engineering units.

dEX Example - Strain Gauge.

Strain Calculation

In this example the mathematics required to convert from frequency is stated on the supplies data sheet as

MicroStrain = GF * (R1^2 – Rz ^2)

Where;
GF = Gauge Factor is 0.0006789
R1 = Current frequency reading
Rz = Zero frequency reading when gauge was installed is 1000 Hz

The steps required are;
1. Configure the *DT80* range *GeoLogger* to read a vibrating wire sensor as described in the quick start section of this document.
2. Add a calculation channel by selecting "Add" -> "Calculation" from the menu bar.

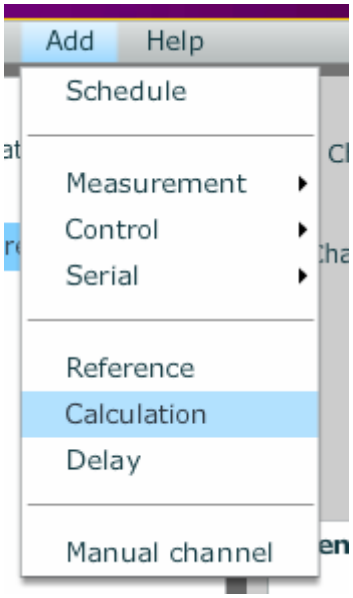

Figure 13 Adding a calculation

3. In the tree view give the channel a unique and meaningful name. To accept the name click on the tick.

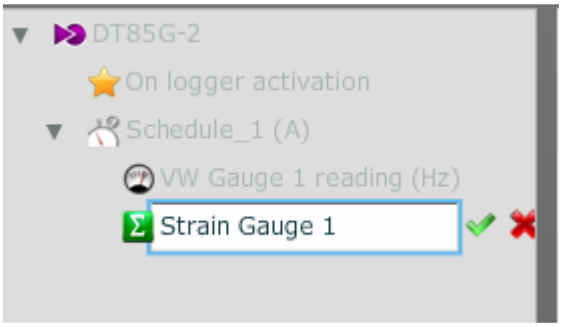

Figure 14 Adding a calculation name

4. To access the calculation builder click in the blank text area next to "Calculation ="

Figure 15 Accessing calculation builder

5. Enter the required calculation.
Note: You can click on the items in the list to add them to the calculation.

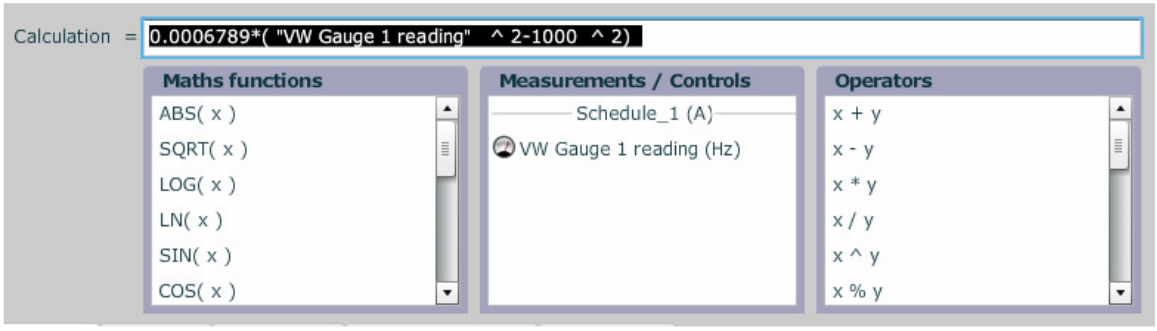

Figure 16 Entering a calculation

6. Enter the channel units ue in the "Display units"

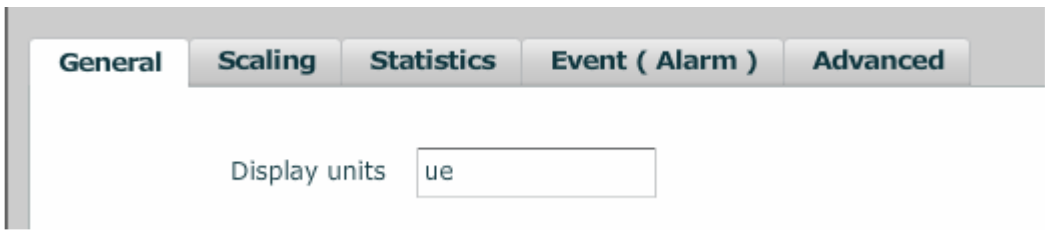

Figure 17 Adding channel units

Strain calculation with temperature compensation

Temperature correction for the gauge can also calculate. The formula will be as per the manufacturer's specification. But usually requires the temperature of the gauge being recorded at time of installation. Knowing the temperature response of the gauge, the strain variation due to temperature effects can be allowed for.

MicroStrain = GF * (R1^2 – Rz ^2)-((T1-Tz)*TF)

Where;
GF= Gauge Factor is 0.0006789
R1 = Current frequency reading
Rz = Zero frequency reading when gauge was installed is 1000 Hz
T1 = Current temperature reading
Tz = Zero Temperature reading (e.g 20 Deg C)
TF = Temperature correction factor (e.g. 11 microstrain per Deg C)

In addition the steps for required for the strain calculation a temperature (Usually a thermistor) sensor needs to be added and the temperature correction added to the strain calculation above

Tuning VWSG sensors

The *DT80G* and *DT85G* have a headphone jack (refer Fig 18) on the back of the data logger which allows the operator to listen to the performance of the vibrating wire sensor with standard head phones. The audio output is very useful if problems when noise or damaged sensors are encountered.

Figure 18 *DT85G* with head phones attached

To listen to the sound of a single gauge the following parameters and switch should be set to;
P62=1 hold last channel open.
P21=1 keep analog section powered after measurement.
/k Turn off house keeping.

Then send the command to read the gauge. (Be sure to restore the setting when finished)

A VWSG should have a crisp clean ping that decays over a number of seconds.
If a clean pinging sound is not heard when the vibrating wire strain gauge is sampled, then the following trouble shooting guide will help diagnose the problem

1. If there is only random noise, check the channel type, wiring and resistance. The resistance measurement should be stable and not show long term drift.
2. If a ping can be heard but it is faint or buried in random noise, then the cable is too long or is "leaky", or the gauge sensitivity is too low.
3. If the ping is not clean and pure, then the gauge is possibly faulty. The gauge may have been mechanically damaged during installation.
4. If you can hear a low frequency hum, then electrical noise pick is a problem.
5. If the gauge is placed near a transformer, electric motor, high current power cables, etc, then relocate or reorient the gauge for minimum pickup. Ensure that the cable is shielded to prevent capacitive pickup.

In some cases performance may be improved by changing the default values of the dataTaker channel factor and measurement delay.

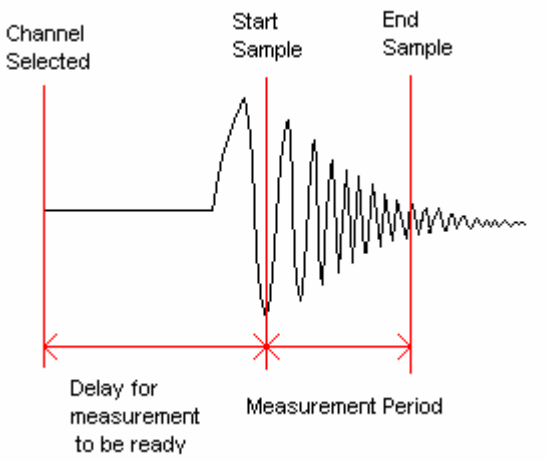

Figure 19 Measurement delay and sample period

Measurement Timing

When an FW channel is evaluated, the measurement process is as follows:

1. The pluck circuit begins charging. The MD timer starts here also.
2. After about 100ms, the pluck circuit releases its energy in the form of a narrow high voltage pulse. Inside the sensor this causes the wire to start vibrating. The resonant frequency will typically be in the range 500-5000Hz.
3. Once the pluck is complete (about 0.2ms), the *DT80G* disconnects the pluck circuit and begins listening to the sensor. Inside the sensor the wire's vibrations are sensed and a corresponding electrical signal is generated.
4. Over the next 100-200ms the *DT80G*'s phase locked loop (PLL) locks on to the fundamental frequency and filters out noise and harmonics. During this time the amplitude of the signal gradually decays as wire's vibrations decay.
5. Once the MD timer expires the *DT80G* will begin measuring the frequency of the filtered signal.
6. Once the required sample period (gate time) has elapsed, the *DT80G* reports the measured frequency value. It is important that the measurement delay is set such that the incoming signal is stable and of adequate amplitude for the duration of the measurement period. The default value is suitable for most gauges, but in some cases it may need adjustment.

Optimizing sample measurement

If a strong and clear signal is heard, but the frequency measurements are unstable (variations of 10-20Hz or more) then there may be strong harmonics present in the gauge's vibration. Because harmonics usually decay faster than the fundamental, it will often help to increase the MD setting. This will mean that the actual frequency measurement phase starts later, at which point the amplitude of the harmonics should be less. If the measurement delay is increased too much, however, the overall signal amplitude may decay below the noise level.

On the other hand if the signal is week then reducing the measurement delay and reducing the sample period will assist in tuning the circuit to optimize the reading.

If the signal is clear but decays rapidly then the default MD setting may in fact be too long – by the time the measurement completes the signal has decayed to nothing.

Some trial and error may be required to find optimal settings. The recommended procedure is as follows. For each step perform several measurements in order to gauge the stability of the readings.

1. Start with minimum values for measurement delay and sample period, e.g. 1FW(MD150,30)
2. Increase the MD setting in, say, 20ms steps until stable readings are obtained, then go one step further.
3. Further improvement can usually be obtained by progressively increasing the sample period so that the frequency is measured over a longer time interval. If this is increased too far however then the signal amplitude will descend into the noise and readings will get rapidly worse.

dataTaker

Training Note

TR-09RD

Programming the *DT80G* data logger

DeTransfer / WEB UI example (Differential Inputs).

Enter the following *dataTaker* code into the send window of *DeTransfer* or the data logger WEB UI command send pane and send to the data logger.

Code example 1:
Vibrating wire strain gauge with strain calculation

```
BEGIN"VWGS"
'Sample Vibrating wire strain gauge.
RA"Schedule_1"("b:",ALARMS:OV:100KB:W60,DATA:OV:1MB)5S
 LOGONA
 1FW("VW Gauge 1 reading~Hz",LM,MD350,200)
 CALC("Strain Gauge 1~ue",LM)=0.0006789*(&"VW Gauge 1 reading"^2-
1000^2)
END
```

Code example 2:
Vibrating wire strain gauge with strain calculation

```
BEGIN"VWGS"
'Sample Vibrating wire strain gauge with temperature compensation.
RA"Schedule_1"("b:",ALARMS:OV:100KB:W60,DATA:OV:1MB)5S
 LOGONA
 1FW("VW Gauge 1 reading~Hz",LM,MD350,200)
 1*YS01(I,"VW Gauge 1 Temp~degC",LM,NA)
 CALC("Strain Gauge 1~ue",LM)=0.0006789*(&"VW Gauge 1 reading"^2-
1000^2)-11*(&"VW Gauge 1 Temp"-23)
END
```


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